June 21, 1894.

The LORD KELVIN, D.C.L., LL.D., President, in the Chair.

Dr. John Rose Bradford and Professor M. J. M. Hill were admitted into the Society.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "Researches on Explosives. Preliminary Note." By Captain Sir A. NOBLE, K.C.B., F.R.S., M.I.C.E., &c. Received June 13, 1894.

The researches on which I, in conjunction with Sir F. Abel, have been engaged for very many years, have had their scope so altered and extended by the rapid advances which have been made in the science of explosives, that we have been unable to lay before the Society the results of the many hundreds of experiments under varied conditions which I have carried out. We are desirous also of clearing up some difficulties which have presented themselves with certain modern explosives when dealing with high densities and pressures, but the necessary investigations have occupied so much time that I am induced to lay a few of our results before the Society, trusting, however, that before long we may be able to submit a more complete memoir.

A portion of our researches includes investigations into the transformation and ballistic properties of powders varying greatly in composition, but of which potassium nitrate is the chief constituent. In this preliminary note I propose to refer to powders of this description chiefly for purposes of comparison, and shall devote my attention principally to gun-cotton and to those modern explosives of which gun-cotton forms a principal ingredient.

In determining the transformation experienced during explosion, the same arrangements for firing the explosive and collecting the gases were followed as are described in our earlier researches,* and the gases themselves were, after being sealed, analysed either under the personal superintendence of Sir F. Abel, or of Professor Dewar,

* 'Phil. Trans.,' vol. 165, p. 61.

and to Professor Dewar's advice and assistance I am indebted, I can hardly say to what extent.

The heat developed by explosion, and the quantity of permanent gases generated were also determined as described in our researches, but the amount of water formed plays so important a part in the transformation that special means were adopted in order to obtain this product with exactness.

The arrangement employed was as follows :—

After explosion the gases formed were allowed to escape through two U-tubes filled with pumice stone and concentrated sulphuric acid; when the gases had all escaped the explosion cylinder was opened, and the water deposited at the bottom of the cylinder was collected in a sponge, placed in a closed glass vessel and weighed. The cylinder was then nearly closed and heated, and a measured quantity of air was, by means of an aspirator, drawn slowly through the U-tubes till the cylinder was perfectly dry. This was easily ascertained by observing when moisture was no longer deposited on a cooled glass tube through which the air passed.

The U-tubes were then carefully weighed, the amount of moisture absorbed determined, and added to the quantity of water directly collected. The aqueous vapour in the air employed for drying was, for each experiment, determined and deducted from the gross amount.

Numerous experiments were made to ascertain the relation of the tension of the various explosives employed, to the gravimetric density of the charge when fired in a close vessel, but I do not propose here to pursue this part of our enquiry, both because the subject is too large to be treated of in a preliminary note and because approximate values have already been published* for several of the explosives with which we have experimented.

With certain explosives, the possibility or probability of detonation was very carefully investigated. In some cases the explosive was merely placed in the explosion vessel in close proximity to a charge of mercuric fulminate by which it was fired, but I found that the most satisfactory method of experiment was to place the charge to be experimented with in a small shell packed as tightly as possible, the shell then being placed in a large explosion vessel and fired by means of mercuric fulminate. The tension in the small shell at the moment of fracture and the tension in the large explosion vessel were in each experiment, carefully measured.

It may be desirable here to explain that I do not consider the presence of a high pressure with any explosive as necessarily denoting detonation. With both cordite and gun-cotton I have developed enormous pressures, close upon 100 tons per square inch (about

* Noble, 'Internal Ballistics,' 1892, p. 33; 'Roy. Soc. Proc.,' vol. 52, p. 128.

15,000 atmospheres), but the former explosive I have not succeeded in detonating, while gun-cotton can be detonated with the utmost ease. It is obvious that if we suppose a small charge fired in a vessel impervious to heat, the rapidity or slowness of combustion will make no difference in the developed pressure, and that pressure will be the highest of which the explosive is capable, regard being of course had to the density of the charge. I say a small charge, because, if a large charge were in question and explosion took place with extreme rapidity, the nascent gases may give rise to such whirlwinds of pressure, if I may use the term, that any means we may have of registering the tension will show pressures very much higher than would be registered were the gases, at the same temperature, in a state of quiescence. I have had innumerable proofs of this action, but it is evident that in a very small charge the nascent gases will have much less energy than in the case of a large charge occupying a considerable space.

The great increase in the magnitude of the charges fired from modern guns has rendered the question of erosion one of great importance. Few, who have not had actual experience, have any idea how rapidly with very large charges the surface of the bore is removed. Great attention has therefore been paid to this point, both in regard to the erosive power of different explosives and in regard to the capacity of different materials (chiefly different natures of steel) to resist the erosive action.

The method I adopted for this purpose consisted in allowing large charges to escape through a small vent. The amount of the metal removed by the passage of the products of explosion, which amount was determined by calibration, was taken as a measure of the erosive power of the explosive.

Experiments have also been made to determine the rate at which the products of explosion part with their heat to the surrounding envelope, the products of explosion being altogether confined. I shall only briefly allude to these experiments, as, although highly interesting, they have not been carried far enough to entitle me to speak with confidence as to final conclusions.

Turning now to ballistic results. The energies which the new explosives are capable of developing, and the high pressures at which the resulting gases are discharged from the muzzle of the gun, render length of bore of increased importance. With the object of ascertaining with more precision the advantages to be gained by length, the firm to which I belong has experimented with a 6-inch gun of 100 calibres in length. In the particular experiments to which I refer, the velocity and energy generated has not only been measured at the muzzle, but the velocity and the pressure producing this velocity have been obtained for every point of the bore, consequently

the loss of velocity and energy due to any particular shortening of the bore can be at once deduced.

These results have been obtained by measuring the velocities every round at sixteen points in the bore and at the muzzle. These data enable a velocity curve to be laid down, while from this curve the corresponding pressure curve can be calculated. The maximum chamber pressure obtained by these means is corroborated by simultaneous observations taken with crusher gauges, and the internal ballistics of various explosives have thus been completely determined.

Commencing with gun-cotton, with which a very large number of analyses were made, with the view of determining whether there was any material difference in the decomposition dependent upon the pressure under which it was exploded, two descriptions were employed: one in the form of hank or strand, and the other in the form of compressed pellets. Both natures were approximately of the same composition, of Waltham Abbey manufacture, containing in a dried sample about 4·4 per cent. of soluble cotton and 95·6 per cent. of insoluble. As used, it contained about 2·25 per cent. of moisture.

The following were the results of the analyses of the permanent gases. They are placed in five series, viz.:—

First. Analyses showing the decomposition of the strand or hank gun-cotton. Second. Analyses showing the decomposition of pellet gun-cotton.

In both these series the analyses are arranged in the order of the ascending pressures under which the decomposition took place.

Third and fourth. Examples of the decomposition of strand and pellet gun-cotton when exploded by means of mercuric fulminate; and, fifth, a series showing the decomposition experienced by pellet gun-cotton saturated with from 25 to 30 per cent. of water, and detonated by means of a primer of dry gun-cotton and mercuric fulminate.

I leave these results for discussion in the memoir which Sir F. Abel and I hope before long to submit, and will only remark that, in Tables I and II, the same peculiarity we have before remarked upon in reference to gunpowder, is again exhibited; I mean the marked manner in which the carbonic anhydride increases with the pressure. It will be noted that in Table I the volumes of carbonic anhydride and carbonic oxide are nearly exactly reversed; again, considering that the composition of the pellet and strand gun-cotton is practically the same, the distinct difference between the proportions of these products in the two series is sufficiently remarkable. It not improbably is connected with the rapidity of combustion of the two samples. Another striking peculiarity is the manner in which the CO_2 is increased (as exhibited in Table V) when saturated pellet cotton is detonated.

I.—Results in Volumes of the Analyses of the Permanent Gases generated by the Explosion of Strand Gun-cotton, arranged according to ascending Pressures.

Under pressure of gas.	Tons per square inch.										
	1·5	2·5	8·0	8·0	12·0	12·3	18·0	20·0	45·0 ?	48·0 ?	50·0 ?
CO_2 ...... (vols.)	26·49	29·62	30·95	31·00	32·23	32·70	33·63	33·01	34·70	34·77	36·18
CO ...... „	36·66	35·03	32·27	32·76	30·65	31·36	31·20	30·32	28·60	28·66	27·57
H .... „	19·68	17·13	19·10	18·80	20·38	19·23	17·99	18·25	16·56	17·48	16·76
N .... „	16·85	18·18	17·20	16·90	16·43	16·25	16·23	16·60	16·83	16·05	16·15
CH_4 ...... „	0·32	0·04	0·48	0·54	0·31	0·46	0·95	1·82	3·31	3·04	3·34

II.—Similar Analyses for Pellet Gun-cotton.

Under pressure of gas.	Tons per square inch.									
	1·0	1·5	6·5	11·0	14·0	15·0	17·0	17·0	25·0	30·0
CO_2 ...... (vols.)	21·50	25·03	25·61	26·68	27·41	25·75	28·54	28·39	28·24	28·88
CO ...... „	39·70	36·85	39·51	36·97	37·23	38·00	35·52	36·41	34·94	35·64
H .... „	22·83	21·00	18·80	19·59	19·37	19·71	18·47	19·64	20·30	20·50
N .... „	15·58	15·88	15·97	15·91	15·35	15·26	16·08	14·90	15·59	14·98
CH_4 ...... „	0·39	1·24	0·11	0·85	0·64	1·28	1·39	0·66	0·93	

III. Results of the Analyses of Strand Gun-cotton when fired in a Close Vessel by Detonation.

	Pressure* per sq. inch.	
	1 ton.	3 tons.
CO_2 (vols.)	19·21	29·08
CO ,, ...	41·25	32·88
H ,, ...	23·07	20·14
N ,, ...	16·21	17·50
CH_4 ,, ...	0·26	0·75

IV. Similar Results for Pellet Gun-cotton.

	Pressure per sq. inch.	
	3 tons.	10 tons.
CO_2 (vols.)	25·76	26·50
CO ,, ...	39·34	37·48
H ,, ...	18·71	20·97
N ,, ...	16·19	15·05
CH_4 ,, ...	Nil	Nil

V. Results of Analyses of Saturated Pellet Gun-cotton fired in a Close Vessel by Detonation.

	Pressure per square inch			
	Under 10 tons.	10·5 tons.	16 tons.	16·5 tons.
CO_2 (vols.)	32·14	33·25	32·93	35·60
CO ,, ...	27·04	25·90	27·25	23·43
H ,, ...	26·80	26·53	25·76	24·22
N ,, ...	13·83	14·32	14·06	15·25
CH_4 ,, ...	0·19	Nil	Nil	1·50

Such are the average analyses of the permanent gases generated by the decomposition of gun-cotton under the various conditions I have described, and it will be evident from these analyses that the volumes of the permanent gases may be expected to differ to some very appreciable extent, depending both upon the density under which it is exploded, and also upon the mode of explosion. I have found it most convenient to explode the charges, the permanent gases from which were to be measured, under a pressure of about 10 tons per square inch (1,524 atmospheres), and, under these circumstances, the average of several very accordant determinations gave, at 0° C. and 760 mm. of mercury, 689 c.c. per gram of strand gun-cotton and 725 c.c. per gram of pellet gun-cotton.

* The pressures given are those due to the gravimetric density of the charge.

At the temperature of explosion the whole of the water formed is in the gaseous state. It is therefore necessary, in order to obtain the total gaseous volume, to add to the above volumes of permanent gases the equivalent volume of aqueous vapour at the temperature and pressure stated. Now the quantity of water formed by the explosion of 129·6 grams of gun-cotton was found to be 16·985 grams; hence 1 gram of gun-cotton generated 0·1311 gram of water, equivalent to 162·6 c.c. of aqueous vapour, and the total volume of gaseous matter at the temperature and pressure stated is for strand gun-cotton 852·2 c.c. per gram, for pellet 887·6 c.c.

The heat measured reached, with strand gun-cotton, 1068 gram-units water fluid, or 988 gram-units water gaseous, while with pellet gun-cotton these figures were 1037 or 957 gram-units respectively.

Pellet gun-cotton made at Stowmarket generated 738 c.c. of permanent gas and 994 units of heat per gram, while dinitro-cellulose containing 12·8 per cent. of nitrogen generated 748 c.c. of gas and 977 units of heat, the water in both cases being fluid.

Gun-cotton, both pellet and strand, I have detonated by means of mercuric fulminate with ease and certainty. The effect of employing this means of ignition in a close vessel is very striking, and the indications of intense heat are much more apparent than when the charge is fired in the ordinary way. This effect is probably partly due to an actual higher temperature, caused by the greater rapidity of combustion. I allude elsewhere to the extreme rapidity with which the gases part with their heat, but this higher heat is, I think, clearly indicated by the surfaces of the internal crusher gauges becoming covered with innumerable small cracks and by thin laminæ occasionally flaking off exposed surfaces; but perhaps the most striking proof of the violence of this detonation is shown by its action on a cast-iron shell fired as I have described; where no detonation takes place the shell is broken into fragments of various sizes, such as are familiar to all acquainted with the bursting of shell; but when detonation, with gun-cotton, for example, takes place, the whole shell is reduced to very minute fragments, and, what is more remarkable, two-thirds of the total weight are generally in the form of small peas and of the finest dust.

The ease with which gun-cotton can be detonated renders it unsuitable for use as a propulsive agent unless this property be in some way neutralised. I have, therefore, made but few experiments in this direction, and shall not further allude to them in this note, as more suitable explosives, explosives also of which gun-cotton is a principal component, have been elaborated, and these not only possess to the full the high ballistic properties of gun-cotton, but are more or less free from the tendency to detonate, which, however useful it may be

in other directions, is a fatal objection to the employment of gun-cotton for propelling purposes.

Turning now to cordite; cordite consists, as is well known, of nitro-glycerine and gun-cotton as its main ingredients. As now made it contains 37 per cent. of gun-cotton (trinitro-cellulose with a small proportion of soluble gun-cotton), 58 per cent. of nitro-glycerine, and 5 per cent. of a hydrocarbon known as vaselin. On account of the importance of this explosive, I have made numerous experiments, both with large and small charges, to determine the relation of the tension to the density of the charge. Up to densities of 0·55 the relation may be considered to be very approximately determined; above that density, although many determinations have been made, these determinations have shown such wide variations that they cannot, until certain discrepancies are explained, be assumed as at all accurate.

The average results of some of the analyses of the permanent gases are given below:—

The first four analyses were made from experiments with the earlier samples of cordite when tannin formed an ingredient of cordite. They are not, therefore, strictly comparable with the later analyses. There appears also to be a difference in the transformation, slight but decided, which the same cordite experiences, dependent upon the diameter of the cord, and this difference is shown at once in the analyses, in the volume of permanent gases, in the heat developed, and, I think, in the amount of aqueous vapour formed.

The following are some of the analyses:—

VI.

	Pressure per square inch.							
	0·048 Cordite.				0·255 Cordite.			
	2·5 tons.	6 tons.	10 tons.	14 tons.	10 tons.	12 tons.	11 tons.	14 tons.
CO_2	29·9	30·4	32·0	31·6	27·0	28·4	23·9	26·3
CO......	28·3	30·7	32·9	32·1	34·2	33·8	37·2	35·8
H	19·3	20·0	18·0	21·6	26·9	24·4	28·4	26·1
N	22·5	18·9	17·1	14·8	12·0	13·4	10·4	11·8
CH_4	traces.							

In the whole of these analyses the water formed by the explosion smelt strongly of ammonia.

The quantity of permanent gases measured, under the same conditions as in the case of gun-cotton, was found to be—

For the earlier cordite, 655 vols.

For the present service cordite, 0·255 in. in diameter, 692 vols., and for that 0·048 in. in diameter, 698 vols. In the two latter samples the aqueous vapour was determined, and was found to

amount to 20·257 grams for the 0·255-in. cordite, and to 20·126 grams for the 0·048-in. cordite; or, stating the result per gram, these figures are respectively equivalent to 0·1563 gram, or 194 c.c. aqueous vapour, and to 0·1553 gram, or 192·5 c.c. per gram of cordite.

Hence the total gaseous products generated by the explosion of cordite amount per gram to 886 c.c. for the 0·255-in. cordite, and to 890·5 c.c. for the 0·048-in. cordite, the volumes being, of course, taken at 0° C. and 760 mm. atmospheric pressure.

The heat generated was found to be:—For the earlier cordite, 1214 gram-units water fluid; for the service 0·255-in. cordite, 1284 gram-units water fluid or 1189 units water gaseous; for the service 0·048-in. cordite, 1272 units water fluid or 1178 units water gaseous.

From my very numerous experiments on erosion I have arrived at the conclusion that the principal factors determining its amount are: (1) the actual temperature of the products of combustion, (2) the motion of these products. But little erosive effect is produced, even by the most erosive powders, in close vessels, or in those portions of the chambers of guns where the motion of the gas is feeble or *nil;* but the case is widely different where there is rapid motion of the gases at high densities. It is not difficult absolutely to retain without leakage the products of explosions at very high pressures, but if there be any appreciable escape before the gases are cooled they instantly cut a way for themselves with astonishing rapidity, totally destroying the surfaces over or through which they pass. Among all the explosives with which I have experimented I have found that where the heat developed is low the erosive effect is also low.

With ordinary powders, the most erosive with which I am acquainted is that which, on account of other properties, is used for the battering charges of heavy guns: I refer to brown prismatic powder. The erosive effect of cordite, if considered in relation to the energy generated by the two explosives, is very slightly greater than that of brown prismatic, but very much higher effects can, if it be so desired, be obtained with cordite, and, if the highest energy be demanded, the erosion will be proportionally greater. There is, however, one curious and satisfactory peculiarity connected with erosion by cordite. Erosion produced by ordinary gunpowder has the most singular effect on the metal of the gun, eating out large holes and forming long rough grooves, resembling a ploughed field in miniature, and these grooves have, moreover, the unpleasant habit of being very apt to develop into cracks; but with cordite, so far as my experience goes, the erosion is of a very different character. The eddy holes and long grooves are absent, and the erosion appears to consist in a simple washing away of the surface of the steel barrel.

Cordite does not detonate; at least, although I have made far more experiments on detonation with this explosive than with any other,

I have never succeeded in detonating it. With an explosive like cordite, capable of developing enormous pressures, it is, of course, easy, if the cordite be finely comminuted, to develop very high tensions, but, as I have already explained, a high pressure does not necessarily imply detonation.

The rapidity with which cordite gases lose their temperature, and consequently their pressure, by communication of their heat to their surrounding envelope is very striking. Exploding a charge of about $1\frac{3}{4}$ lbs. of cordite in a close vessel at a tension of a little over 6 tons on the square inch, or say 1000 atmospheres, I have found that the pressure of 6 tons per square inch was again reached in 0·07 sec. after explosion, of 5 tons in 0·171 sec., of 4 tons in 0·731 sec., of 3 tons in 1·764 secs., of 2 tons in 3·523 secs., and of 1 ton in 7·08 secs. The loss of pressure after 1 ton per square inch was reached was, of course, slow, but the figures I have given were closely approximated to in two subsequent experiments. With ordinary gunpowder the reduction of pressure was very much slower, as was to be expected, on account of the charge being much larger; on account, also, of the temperature of explosion being much lower.

These experiments are now being continued with larger charges and higher pressures.

It only remains to give particulars as to ballistics, that is as to the velocities and energies realisable by cordite in the bore of a gun, but these will be most conveniently given with similar details regarding other explosives with which I have experimented.

The ballistite I have used has, like the cordite, been changed in composition since the commencement of my experiments. The sample I used for my earlier experiments was nearly exactly composed of 50 per cent. of dinitro-cellulose (collodion cotton) and 50 per cent. of nitro-glycerine. The cubes were coated with graphite, and the nitro-cellulose was wholly soluble in ether alcohol.

The second sample was nominally composed of 60 per cent. of nitro-cellulose and 40 per cent. of nitro-glycerine. The proximate analysis gave

Nitro-glycerine	41·62
Nitro-cellulose	59·05

as before the whole of the nitro-cellulose was soluble in ether alcohol.

The earlier sample gave the following permanent gases under pressures of six and twelve tons per square inch respectively.

CO_2	37·3	38·49
CO	27·8	28·35
H	19·1	19·83
N	15·8	13·32
CH_4	traces.	

One gram of this ballistite gives rise to 610 c.c. of permanent gases, and to 0·1588 gram of aqueous vapour corresponding to 197 c.c. at 0° C and 760 mm.

Hence the total volume of gas is 807 c.c., and the heat generated by the explosion is 1,365 gram-units (water fluid), 1,269 gram-units (water gaseous).

Although I have not made nearly so many experiments on detonation with ballistite as with cordite, those I have made with the earlier samples (50 per cent. gun-cotton and 50 per cent. nitro-glycerine) neither detonated, nor did they show any tendency to detonate, but the case is different with respect to a sample of ballistite consisting of 60 per cent. gun-cotton and 40 per cent. nitro-glycerine. This sample, 0·2-in. cubes, detonated with great violence on two occasions, but I am unable, without further experience, to say whether this result was due to the change in the composition of the ballistite or to defective manufacture.

The erosive action of ballistite is, as might perhaps be anticipated from the higher heat developed, greater than with cordite, but the remarks made with respect to the action of cordite apply also to ballistite.

The French B.N. powder consists of nitro-cellulose partially gelatinised and mixed with tannin, with barium and potassium nitrates.

When exploded under a pressure of six tons per square inch the permanent gases were found to consist of

CO_2	28·1 vols.
CO	32·4 ,,
H	21·9 ,,
N	16·8 ,,
CH_4	0·8 vol.

These permanent gases occupied at the usual temperature and pressure a volume of 616 c.c.; the aqueous vapour formed occupied in addition 206 c.c., so that the total gaseous volume was 822 c.c.

The heat generated was 1,003 gram-units (water fluid) or 902 gram-units (water gaseous); the ballistics obtained with this powder are given along with those furnished by other explosives.

For purposes of comparison I have introduced among the ballistic results those obtained with amide prismatic powder, and with R.L.G. Particulars as to both these powders have already been given* and need not here be repeated.

In a preliminary note like the present, the most convenient mode

* 'Roy. Soc. Proc.,' vol. 52, p. 125; 'Phil. Trans.,' Part I, 1880, p. 278.

of comparing the velocities and energies developed by the new explosives is by the aid of diagrams.

Accordingly, in Fig. 1, I show the velocities of seven different explosives from the commencement of motion to the muzzle of the gun; the position of the points at which the velocity is determined are shown, and on the lowest and highest curves the observed velocities are marked where it is possible to do so without confusing the diagram. Lines are drawn to indicate the velocities that are obtained with the lengths of 40, 50, 75, and 100 calibres.

Fig. 2 shows the pressures by which the velocities of Fig. 1 were obtained. The areas of these curves represent the energies realised, and the lines intersecting the curves indicate the pressures at which the gases are discharged from the muzzle for lengths of 40, 50, 75, and 100 calibres respectively. The chamber pressures indicated by crusher gauges are also shown in Fig. 2, and it will be observed that the two modes of determining the maximum pressure are in general in close accordance.

It will further be observed that with the slow-burning powders the chronoscopic maximum pressures are somewhat, though not greatly higher, than are those indicated by the crusher gauges. This observation is not new.* It was noted in the long series of experiments with black powders carried on by the Committee of Explosives.

The result is widely different where an explosive powder or a quickly-burning powder, such as R.L.G., giving rise to wave-pressure is employed; the crusher gauge in such cases† gives considerably and frequently very greatly higher pressures, and this peculiarity is illustrated in the curve from R.L.G. in Fig. 2.

It is, perhaps, hardly necessary to point out that the results given in Fig. 1 have to be considered in relation to the facts disclosed in Fig. 2. Thus it will be noted that the velocities and energies realised by 22 lb. of 0·35-in. cordite and 20 lb. of 0·3-in. cordite are practically the same, but reference to Fig. 2 shows that with the 0·3-in. cordite this velocity and energy has been obtained at the cost of nearly 30 per cent. higher maximum pressure.

A similar remark may be made in regard to the French B.N. powder if compared with the ballistite. Its velocity and energy are obtained at a high cost of maximum pressure, and it is interesting to note how the velocity curve of B.N., which for the first four feet of motion shows a velocity higher than that of any other explosive, successively crosses other curves, and gives at the muzzle a velocity of 500 f.s. under that of cordite.

The velocities and energies at the principal points indicated in

* Noble and Abel, 'Phil. Trans.,' vol. 165, p. 110.

† Compare Noble and Abel, *loc. cit.*, p. 109.

Fig. 1.

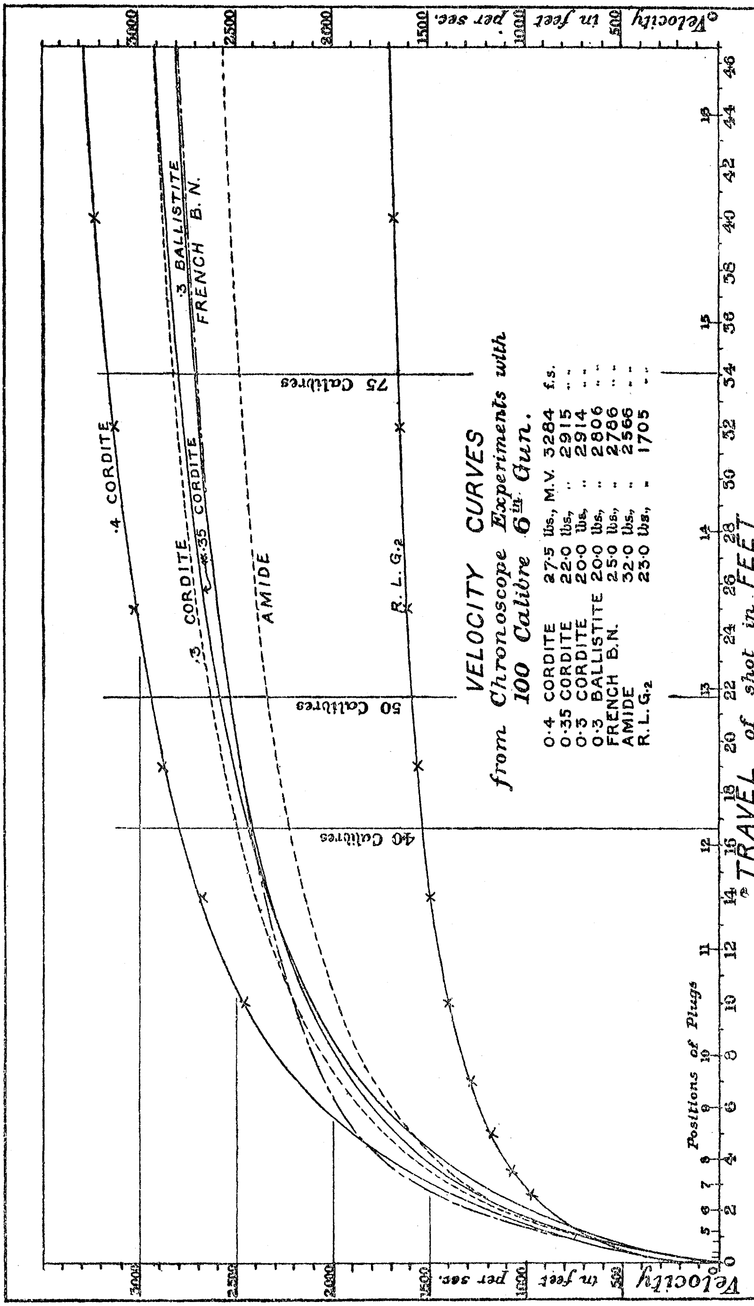
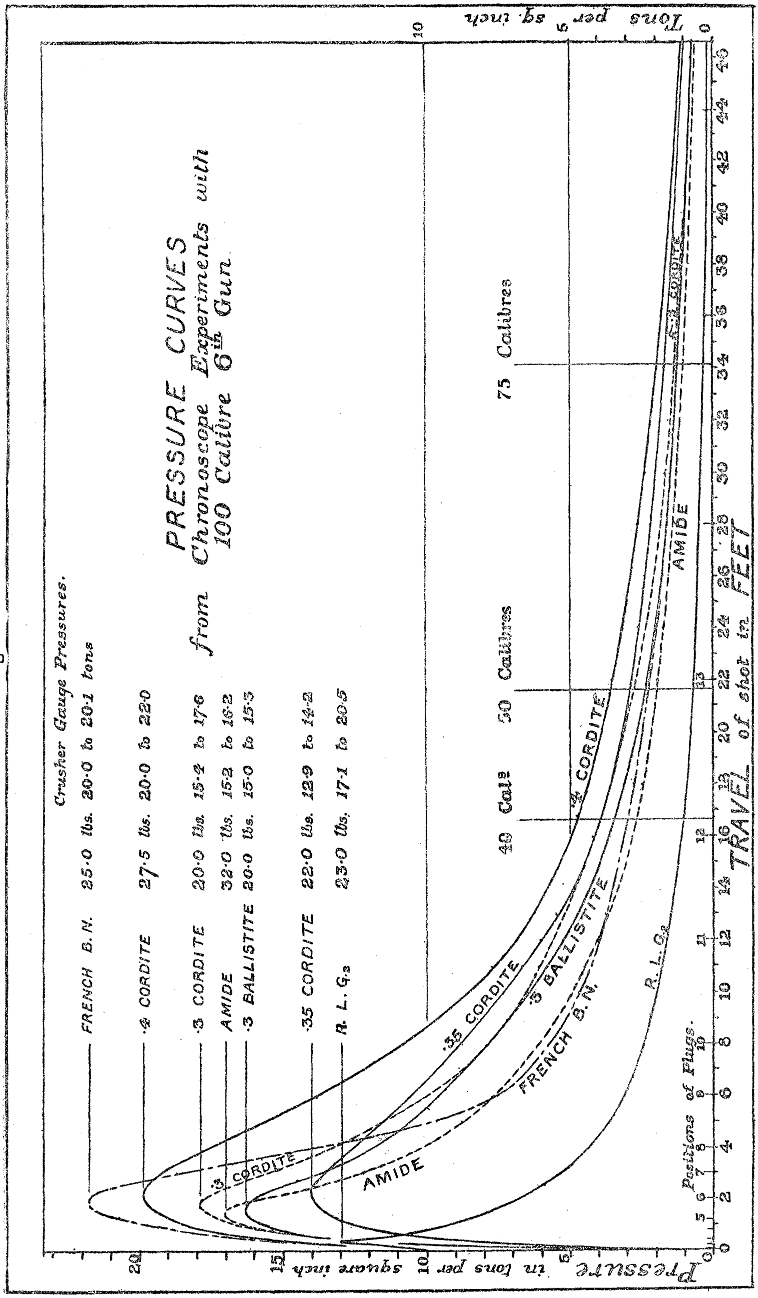

VELOCITY CURVES
from Chronoscope Experiments with
100 Calibre 6in Gun.
0·4 CORDITE 27·5 lbs., M.V. 3284 f.s.
0·35 CORDITE 22·0 lbs., " 2915 "
0·3 CORDITE 20·0 lbs., " 2914 "
0·3 BALLISTITE 20·0 lbs., " 2806 "
FRENCH B.N. 25·0 lbs., " 2786 "
AMIDE 32·0 lbs., " 2566 "
R.L.G.2 23·0 lbs., " 1705 "
·4 CORDITE
·3 CORDITE
·35 CORDITE
·3 BALLISTITE
FRENCH B.N.
AMIDE
R.L.G.2
75 Calibres
50 Calibres
40 Calibres
Velocity in feet per sec.
TRAVEL of shot in FEET
Positions of Plugs

Fig. 2.


PRESSURE CURVES
from Chronoscope Experiments with
100 Calibre 6in Gun
Crusher Gauge Pressures.
FRENCH B.N. 25·0 lbs. 20·0 to 20·1 tons
·4 CORDITE 27·5 lbs. 20·0 to 22·0
·3 CORDITE 20·0 lbs. 15·4 to 17·6
AMIDE 32·0 lbs. 15·2 to 16·2
·3 BALLISTITE 20·0 lbs. 15·0 to 15·5
·35 CORDITE 22·0 lbs. 12·9 to 14·2
R. L. G.2 23·0 lbs. 17·1 to 20·5
40 Cals
50 Calibres
75 Calibres
Pressure in tons per square inch
Tons per sq. inch
TRAVEL of shot in FEET
Positions of Plugs.
·35 CORDITE
·3 BALLISTITE
FRENCH B.N.
R. L. G.2
·3 CORDITE
AMIDE
·4 CORDITE

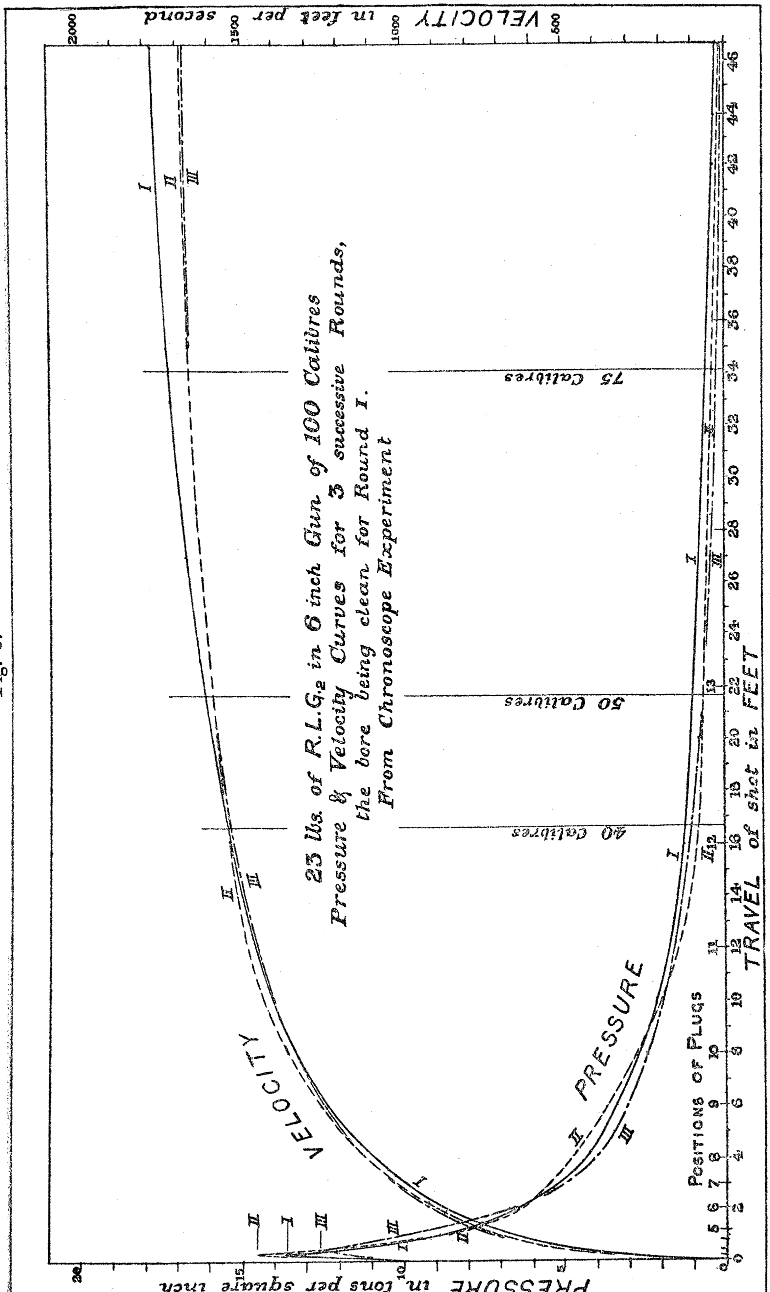

23 lbs. of R.L.G.2 in 6 inch Gun of 100 Calibres
Pressure & Velocity Curves for 3 successive Rounds,
the bore being clean for Round I.
From Chronoscope Experiment
VELOCITY in feet per second
PRESSURE in tons per square inch
TRAVEL of shot in FEET
POSITIONS OF PLUGS
75 Calibres
50 Calibres
40 Calibres
VELOCITY
PRESSURE

Fig. 3.

Table showing the Velocities and Energies realised in a 6″ Gun with the undermentioned Explosives.

Nature of explosive and weight of charge.	Length of bore, 40 calibres.		Length of bore, 50 calibres.		Length of bore, 75 calibres.		Length of bore, 100 calibres.	
	Velocity.	Energy.	Velocity.	Energy.	Velocity.	Energy.	Velocity.	Energy.
Cordite, 0·4″ dia., 27·5 lbs.	2794	5413	2940	5934	3166	6950	3284	7478
Cordite, 0·35″ dia., 22 lbs.	2444	4142	2583	4626	2798	5429	2915	5892
Cordite, 0·3″ dia., 20 lbs.	2495	4316	2632	4804	2821	5518	2914	5888
Ballistite, 0·3″ cubes, 20 lbs.	2416	4047	2537	4463	2713	5104	2806	5460
French B.N., 25 lbs.	2422	4068	2530	4438	2700	5055	2786	5382
Amide Prismatic, 32 lbs.	2225	3433	2331	3768	2486	4285	2566	4566
R.L.G.$_2$, 23 lbs.	1533	1630	1592	1757	1668	1929	1705	2016

Figs. 1 and 2 are summarised in the annexed table, which shows for each nature of explosive the advantage in velocity and energy to be gained by correspondingly lengthening the gun.

Fig. 3 is an interesting illustration of a point to which I have elsewhere adverted. Cordite and ballistite leave no deposit in the bore. Round 1 with R.L.G. was fired with a clean bore. The difference in velocity between round 1 with a clean bore and rounds 2 and 3 with powder deposit in the chase is very clearly marked, and it will be noted that in this instance the effect of the foul bore is only distinctly shown when the length exceeds 40 calibres.

From 40 calibres onwards the loss of velocity due to a bore encrusted with deposit is very distinctly shown.

II. "Measurement of Colour produced by Contrast." By Captain W. DE W. ABNEY, C.B., D.C.L., F.R.S. Received June 5, 1894.

No definite measurements, as far as I am aware, have been made of the change in colour produced by contrast, except in a small work of my own in which results were given in terms of colour mixtures, and earlier by a brief reference in a work by Rood, in which the change produced was endeavoured to be matched by means of rotating disks.

The method of registering any colour in terms of some definite wave-length of light, together with white light (see 'Proceedings Royal Society,' vol. 49) renders the registration of any colour readily effected, and by applying it to the contrast colours, very fair results have been obtained, which cannot be very far from the truth. It is usually stated that the contrast colour produced on a white surface by an adjacent colour is the complementary colour, of course largely diluted with white light. I should like to point out that in the first place we have to know what a complementary colour is, and in the second what the added white light may be. As a matter of fact the kind of white light employed has to be defined before it can be stated what the complementary to any colour may be. If, for instance, we wish to define what the complementary of orange may be, we must know what is the nature of the white light before we can give the complementary. Suppose we take the white of daylight, or of the electric light, we know that to make a white of this character we must add a certain quantity of blue of a certain wave length to the orange. When it is produced under these circumstances, the blue is the complementary to the orange. Suppose, however, we wish to know the complementary to the orange, in what is called the white light of the amyl acetate lamp, or of a candle, we are at once met by a difficulty.